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Detecting Posture Mirroring in Social Interactions with Wearable Sensors

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Abstract

We envision wearable social-behavioral assistants which measure the nonverbal behavior of their users during social interaction. Research in psychology has linked posture mirroring, a key element of nonverbal behavior, to rapport and empathy and has been found to support communication. In this paper, we present a method to measure posture mirroring in social interaction with body-worn motion sensors. Our method is based on the detection of basic posture classes and the comparison of displayed postures across group members. We apply our method in a group discussion scenario involving 42 groups consisting of three subjects each in which group leaders express different leadership styles. Our results show that we can measure differences in posture mirroring across groups of different leadership styles.

1 Introduction

The automatic detection of nonverbal cues such as body movement from sensor data provides a way to capture aspects of human behavior. In the field of wearable computing Pentland and collaborators investigated how sociometric badges can be used to describe aspects of human behavior such as physical activity, speech activity and face-to-face interaction [4]. Another important nonverbal cue in social interaction has been termed posture mirroring and its detection is the focus of this paper. Posture mirroring occurs when persons display similar postures while interacting with one another. Research in psychology has linked posture mirroring to increase rapport and empathy and to support communication [2]. The relationship between posture sharing and self-report on rapport was examined by LaFrance [3]. Two observers coded upper body postures of teachers and students in a class room. A student's posture was categorized as mirroring, if her posture was a mirror image of the teacher's posture, e.g. the student's left arm matched the right arm of the teacher. In case that the stu-

dent's left arm matched the left arm of the teacher, it was noted as congruent posture. Mirroring and congruent postures were then combined to a posture-sharing index.

Current approaches used in social psychology to capture posture mirroring often rely on manual annotation of video recordings and are thus labor intensive, time consuming and prone to error. In this paper, we present a novel method to measure posture mirroring in social interaction with body-worn motion sensors.

2 Experiment

We set-up an experiment in which participants were discussing in groups of three. Fifty-five groups were asked to work on a decision making task to rank four fictive candidates with regard to their suitability for an open job position. Under the guidance of the leader the group had to discuss the suitability of each candidate and agree on a rank order. Half of the leaders were instructed to show individual considerate leadership, e.g. to stimulate their followers to contribute their own opinions, whereas the other half was instructed to be authoritarian, e.g. interrupt unsuitable contributions of followers.

The upper body motion of the participants was captured with six inertial measurement units (IMU, XSens MTx) which were located on both lower and upper arms, the back and the head. All sensors were sampled with a frequency of 32 Hz. For an easier and shorter setup the IMUs were integrated into a *sensor-shirt*, a long-sleeve stretch shirt which allowed identical sensor placement for all participants. Additional elastic straps were used to fixate the sensors on the subject's body. For the synchronous recording of the motion data we used the CRN-Toolbox [1].

In total, we recorded data from 165 subjects (112 female, 53 male; age = 25.4 ± 4.2) in 55 group discussions. Due to a sensor problem in one of the sensor shirts at the beginning of the experiment we lost sensor data of 13 subjects. In consequence, our data set includes 42 group discussions with three participants each and totals to 15 hours of discussion time.

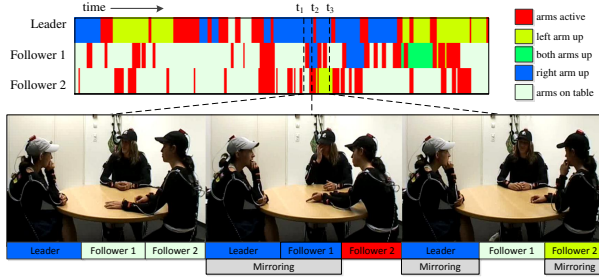


Figure 1. Extract of detected posture stream. Close ups represent 3 time steps. Posture mirroring occurs in the 2nd and 3rd time step.

3 Mirroring Detection

Similar to the early works of LaFrance [3], our automatic mirroring detection relies on a set of basic arm postures.

In this work, we focus on the following set of basic posture classes: $X = \{\text{left-arm-up}, \text{right-arm-up}, \text{both-arms-up}\}$. Thresholding on the standard derivation of the acceleration magnitude (STDAM) over a sliding window ($N = 1\text{ s}$, $P = 0.5\text{ s}$), we consider a participant to be active when the STDAM of one of the lower arm sensors exceeds a threshold $\theta_{std} = 0.3 \frac{\text{m}}{\text{s}^2}$. For each nonactive segment longer than one second we detect the posture class. We use a Naive Bayes classifier on the Euler angles measured by the orientation sensors on the lower arms. Ground truth training data was acquired by manually annotating about 10% of the non active segments that were obtained by the segmentation process. Using 10-fold cross-validation the performance of the classifier was evaluated as close to 98% in precision and recall. The detected postures build the basis of our mirroring extraction method.

Contrary to LaFrance, who counted mirroring occurrences in intervals of one minute, we measure the duration of posture mirroring. A detected posture class at time step t for group member S_i is represented by $x_{t,i} \in X$. We calculate the amount of mirroring that a group member S_i receives from other group members $S_{j \neq i}$ while displaying posture x as:

$$P(S_i \text{ is mirrored} | x) = \frac{\sum_t \bigcup_{j \neq i} \text{similar}(x, x_{t,j})}{\sum_t x_{t,i} == x}, \quad (1)$$

in which $\text{similar}(x, x_{t,j})$ is an operator that returns one if the detected posture $x_{t,j}$ is a mirrored or congruent posture of x and zero otherwise. The amount of mirroring that a group member S_i receives by any other group member is given by the expectation of Eq. 1 over the set of postures X . Finally, as we are interested to measure the average amount

of posture mirroring taking place in one group discussion, we average over all group members. Groups that have an average mirroring value greater 5% are regarded as groups that show mirroring behavior.

4 Results

An intermediate result of our mirroring extraction method is the stream of detected posture classes which is illustrated in Figure 1. Given the posture stream we can calculate how long a posture is shown in terms of discussion time. We observed that the posture classes *left-arm-up*, *both-arms-up* and *right-arm-up* were shown for five percent of the discussion time in the mean over all discussions. We also noticed that the group leader is significantly more active with her arms than the followers (two-sample t-test, $p \ll 1\%$). Analysing the amount of mirroring, we noticed that posture mirroring does not occur in 8 discussions, whereas in 34 discussions the amount of average mirroring is between 0.6% and 50% of time that a posture is displayed. Comparing the groups of different leadership style, we could observe differences in their mirroring behavior. Groups with an individually considerate leader showed posture mirroring in 80% of 21 discussions, whereas groups with an authoritarian leader showed mirroring behavior only in 47% of 21 discussions. In conclusion, we have presented a method to measure posture mirroring in social interaction with wearable sensors. This work represents a step towards our goal of a social-behavioral assistant to objectively measure nonverbal cues such as posture mirroring outside the lab. In future, additional posture classes in the context of mirroring have to be analysed.

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